

Striped Nanorods

The research group of Senior Faculty Scientist Paul Alivisatos has made one-dimensional “superlatticed” nanorods for the first time. Superlatticed semiconductor structures with alternating layers of different compositions are highly valued for their potential as components of transistors, biochemical sensors and light-emitting diodes (LEDs) but, to date, have only been made by relatively expensive and exacting processes.

Today’s electronics industry is built on two-dimensional semiconductor materials that feature carefully controlled doping and interfaces, including the use of superlatticed structures. Tomorrow’s industry may be built upon one-dimensional materials and superlatticed structures with their predicted outstanding electronic and photonic properties playing a key role in the device application. One-dimensional striped nanorod structures have been made using an epitaxial processes, in which the rods are attached to or embedded within a solid medium. However, this process is relatively expensive.

The key to making striped nanorods using inherently inexpensive solution-phase processing lay in adopting certain “strain engineering” methodologies used for thin film superlattice deposition. Previous research by Alivisatos and his group had shown that “exchange of cations” could be used to vary the proportion of two semiconductors within a single nanocrystal without changing the crystal’s size and shape. *Ab initio* calculations performed by Lin-Wang Wang and co-workers in LBNL’s Computational Sciences Division suggested that if only a fraction of the cations were exchanged, the naturally occurring strain due to the change in composition could be the driving force for inducing the spontaneous formation of superlattice structures.

Working with cadmium-sulfide nanorods, the team engineered cation exchange with the semiconductor silver sulfide in free-standing quantum dots. As predicted by the computer simulations, they found that a linear arrangement of regularly spaced silver sulfide bands appeared in the cadmium sulfide nanorods when approximately 36% of the cations were exchanged. The resulting striped nanorods display properties expected of an epitaxially prepared array of silver sulfide quantum dots separated by confining regions of cadmium sulfide, including the ability to emit near-infrared light.

This colloidal approach to making striped nanorods may well lead to their use in biological labeling and in solution-processed LEDs and solar cells. Even though the colloidal striped nanorods form spontaneously, the computer modeling suggests that it should be possible to control their superlatticed pattern—hence their properties—by adjusting the length, width, composition, etc., of the original nanocrystals.

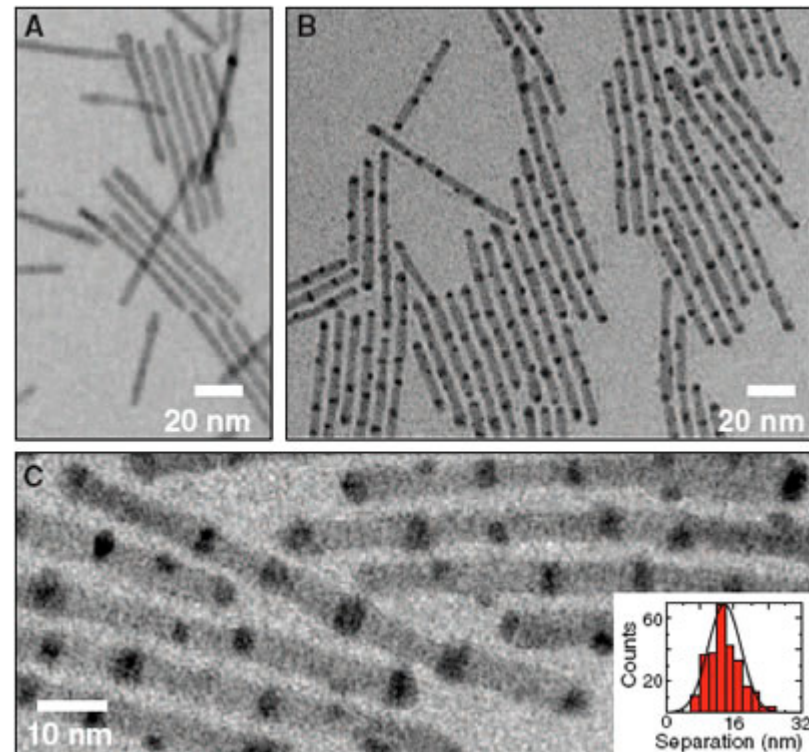
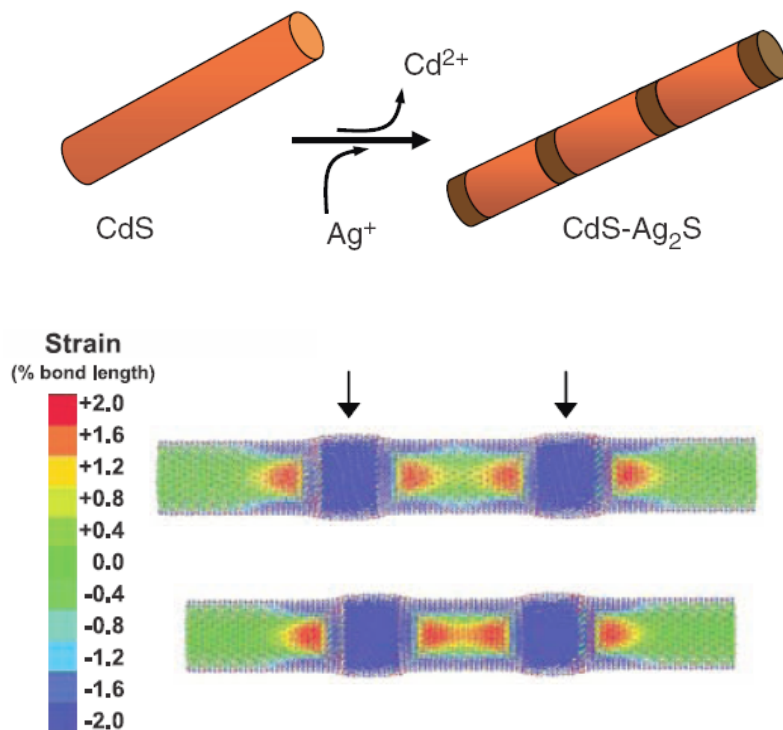
A. P. Alivisatos, (510) 486-4999, Materials Sciences Division (510) 486-4755, Berkeley Lab.

R. D. Robinson, B. Sadtler, D. O. Demchenko, C. K. Erdonmez, L.-W. Wang, A. P. Alivisatos, “Spontaneous Superlattice Formation in Nanorods Through Partial Cation Exchange,” *Science* **317** 355 (2007).

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Partial exchange of Ag ions for the Cd cations in CdS nanorods leads to the formation of nanorods with a alternating of CdS/Ag₂S layers.
Ab-initio calculations (below) predicted the strain driving force that causes the superlattice structure to form.



Transmission Electron Microscope images of superlatticed (striped) nanorods formed through partial cation exchange, (A) original cadmium-sulfide nanorods; (B and C) cadmium-sulfide nanorods striped with silver-sulfide. Histogram (inset) shows the regularity of the pattern spacing of the silver-sulfide stripes.